ECOLOGY AND FISHERIES OF SELECTED RESERVOIRS OF ANDHRA PRADESH

Central Inland Capture Fisheries Research Institute
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
Barrackpore 743101 West Bengal

ECOLOGY AND FISHERIES OF SELECTED RESERVOIRS OF ANDHRA PRADESH

Bull. No. 85 Oct. 1998

Central Inland Capture Fisheries Research Institute
(Indian Council of Agricultural Research)
Barrackpore-743 101 West Bengal

Ecology and Fisheries of Selected Reservoirs of Andhra Pradesh

ISSN 0970-616 X

Composed at : **The Project Monitoring & Documentation Section**
CIFRI Barrackpore

Assistance : Sefali Biswas
Cover design : P. Dasgupta

Published by : **The Director,** CIFRI Barrackpore

Printed at : Calcutta Laser Graphics (Pvt.) Ltd.
71, Hari Ghosh Street
Calcutta 700 006

Foreword

The reservoirs in India constitute the most important inland fishery resource of India with immense potential to enhance the country's inland fish production in the coming years. Keeping this aspect in view CIFRI initiated scientific investigations on the ecology and fisheries in various reservoirs situated in different states of India. As part of this study scientists of CIFRI surveyed selected reservoirs of Andhra Pradesh for two years and this publication is a documentation of the research data generated during two years.

I am hopeful that this document will greatly help in formulating guidelines for scientific management of said reservoirs in Andhra Pradesh.

I place on record the valuable cooperation received from the Department of Fisheries, Andhra Pradesh during the investigation. Their unflincing support has helped us achieve our target.

M. Sinha

Investigating Team

Sri Ch.Gopalakrishnayya, ***Principal Scientist & Project Leader***	**Morphometric and hydrological features, Fish catch statistics**
Dr. A.K.Das, ***Scientist***	**Soil and water quality** **Primary production** **Heavy metals and Pesticides**
Dr. M. Ramakrishniah, ***Sr. Scientist***	**Bottom macrofauna**
Dr. P.K.Sukumaran, ***Sr. Scientist***	**Plankton**
Manuscript preparation	***Dr. M. Ramakrishniah*** ***Dr. A.K. Das***

Contents

****

Introduction

Reservoirs are the prime inland fishery resource of India having a great potential to enhance the country's inland fish production several fold. The southern state of Andhra Pradesh is endowed with rich inland waters consisting of rivers, reservoirs and tanks. The two main rivers of peninsular India, the Godavari and the Krishna flow through the state. Several reservoirs have been constructed on these river systems to harness them for multipurpose use. The state also has numerous small rivers and streams whose potential for irrigation has been tapped by impounding their waters. The total waterspread under reservoirs and tanks of the state has been estimated at 4.58 lakh hectares, the former accounting for 2.8 lakh ha and the later 1.78 lakh ha. Though the state has made rapid strides in the field of aquaculture achieving record production levels, fish yield from reservoirs remain at low level due to low priority given for their development. There is tremendous scope to enhance the inland fish production of the state substantially through scientific management of reservoirs. However, hardly any database exists on the ecology, fishery potential and status of fisheries development of reservoirs in the state.

In order to understand the ecology and fish yielding potential, an exploratory survey on selected reservoirs of Andhra Pradesh was undertaken during July 1995 to December 1996. The survey also envisaged a probe into the present status of fisheries development and management of different reservoirs so as to formulate guidelines for their scientific management.

Reservoirs selected for study

Nine reservoirs were selected from three river systems of the state. They are : Nagarjunasagar, Srisailam, Musi and Wyra from the Krishna system, Singur, Kadam and Lower Manair Dam (LMD) from the Godavari system, Mid Penna Dam (MPD) and Somasila from Penna system. Srisailam and Nagarjunasagar are the mainstream reservoirs of Krishna, while Musi and Wyra are on its tributaries. Singur, Kadam and LMD are on the tributaries of Godavari *viz.* Manjira, Kadam and Manair respectively. MPD and Somasila are mainstream reservoirs of Penna (Fig. 1). Most of the reservoirs are designed for irrigation. Srisailam is mainly a hydel power project and power component is also incorporated in Nagarjunasagar. From Srisailam reservoir 15 TMC of water is being supplied to the city of Chennai through Telugu Ganga Canal. Somasila also acts as a pickup reservoir for Telugu Ganga Canal. Singur is exclusively meant for water supply to the city of Hyderabad. LMD, besides being an irrigation project serves as a balancing reservoir for Kakatiya canal originating from Sriramsagar reservoir on Godavari. Similarly MPD is also a balancing reservoir for high level canal of the Tungabhadra reservoir.

Nagarjunasagar has been studied in detail during 1971-81 under the All India Co-ordinated Research Project on Ecology and Fisheries of Freshwater reservoirs. In order to understand the present status of Nagarjunasagar after one and a half decades of study, the reservoir has been included in the present survey. Recently Srisailam Dam has come up at the head-end of N. Sagar which is likely to have its impact on its ecology and fisheries.

Sampling procedure

The reservoirs have been sampled during three seasons ; Pre-monsoon (April-may), Monsoon (August-September) and Post-monsoon (October-November). The studies cover morphometric and hydrological characteristics, soil and water quality parameters, carbon production, abundance of fish food resources and fish catch composition. The status of pollution in different reservoirs due to discharge of industrial effluents and sewage and concentration of heavy metals in sediments and water were also studied. Standard methods were employed for sampling and analyses.

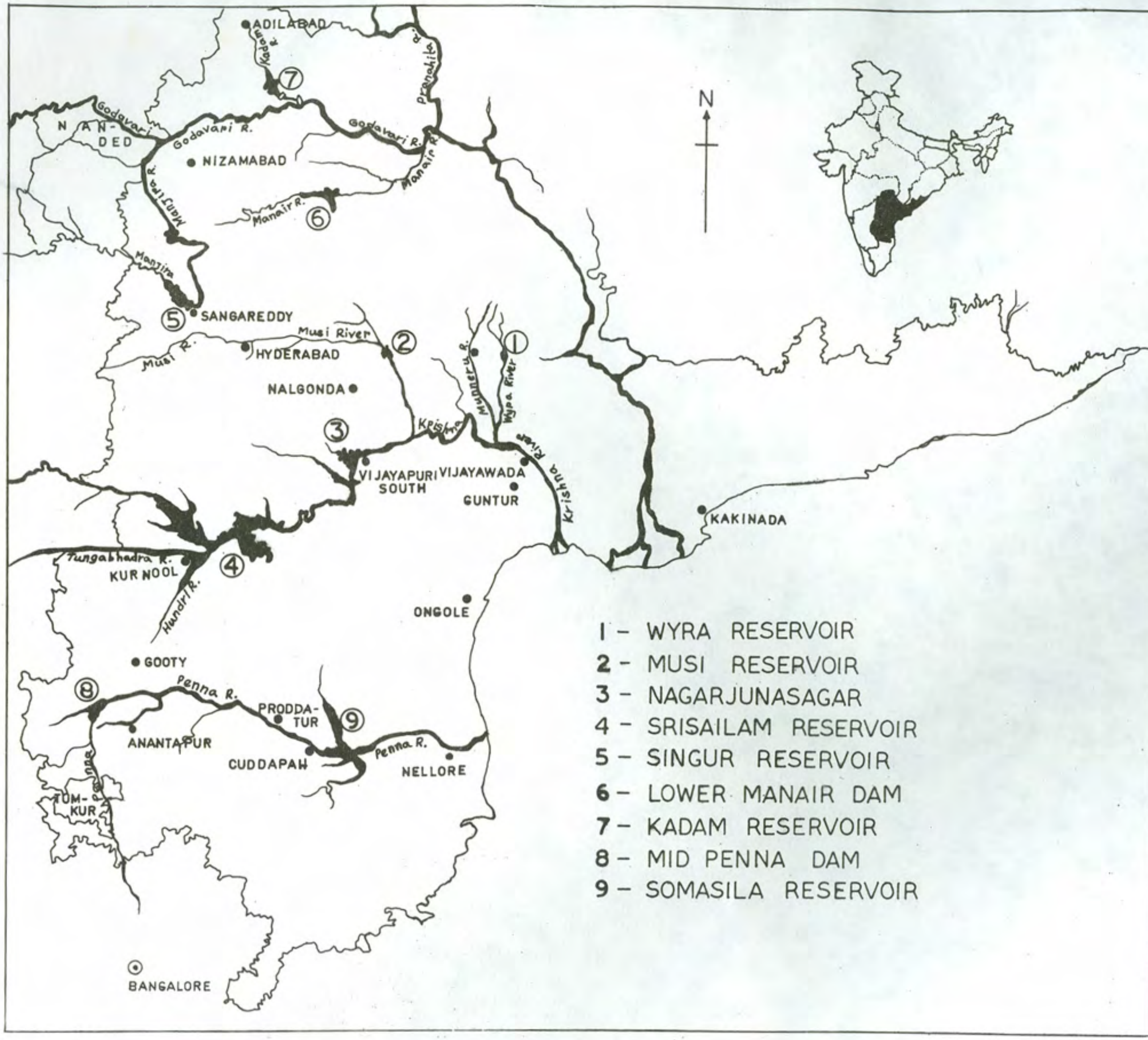
Morphometric and hydrological characteristics

Table 1 summarises various morphometric and hydrological parameters of selected reservoirs. The reservoirs are located in the tropical belt between latitudes 14° 29' N and 19° 18' N at elevations ranging from 95.8 m (MSL) to 523.6 m (MSL). Srisailam is the largest reservoir with an average waterspread of 33,689 ha. Others in the category of large reservoirs are Nagarjunasagar (18,429 ha), Singur (8,700 ha), Somasila (12,695 ha) and LMD (4,833 ha). Average area of MPD (889 ha) puts it in small reservoir category while other, are Wyra (1,074 ha), Kadam (1,842 ha) and Musi (1,400 ha), fall in the medium reservoir category. Wyra is the oldest impoundment having been formed in 1930 while Srisailam (1984), Somasila (1988), LMD (1986) and Singur (1989) are the recent ones. Nagarjunasagar is the deepest with a mean depth of 40.5 m and the shallowest being Wyra (m.d 3.9 m). Barring Srisailam (14.2 m) and Somasila (10.3 m), all others had mean depth below 10 m. The catchment of all reservoirs lie in the dry Deccan plateau which include forests and intensely cultivated agricultural and waste lands with moderate to low rainfall. The ratio of catchment to reservoir area (considered to be an index of allochthonous inputs)

Sampling in Nagarjunasagar Reservoir

A haul of catfish from Nagarjunasagar Reservoir

A catch of Indian Major Carp from Nagarjunasagar Reservoir



ADILABAD
Kadam R.
Godavari
N AN-DED
Godavari R.
NIZAMABAD
Manjira R.
Manair R.
Manjira
SANGAREDDY
Musi River
Musi R.
HYDERABAD
NALGONDA
Munneru R.
Wyra River
Krishna
VIJAYAPURI SOUTH
VIJAYAWADA
GUNTUR
Krishna River
KAKINADA
Tungabhadra R.
KURNOOL
Hundri R.
ONGOLE
GOOTY
Penna R.
PRODDA-TUR
ANANTAPUR
CUDDAPAH
NELLORE
TUM-KUR
BANGALORE
N
1 - WYRA RESERVOIR
2 - MUSI RESERVOIR
3 - NAGARJUNASAGAR
4 - SRISAILAM RESERVOIR
5 - SINGUR RESERVOIR
6 - LOWER MANAIR DAM
7 - KADAM RESERVOIR
8 - MID PENNA DAM
9 - SOMASILA RESERVOIR

Table 1. Location, morphometric and hydrological features of reservoirs of A.P.

River System	**Krishna River System**				**Godavari River System**			**Penna River System**	
Reservoir	*Wyra*	*Musi*	*N. Sagar*	*Srisailam*	*Singur*	*LMD*	*Kadam*	*MPD*	*Somasila*
River	Wyra	Musi	Krishna	Krishna	Manjira	Manair	Kadam	Penna	Penna
Latitude (N)	17°11'	17°14'	16°34'	16°50'	17°45'	18°24'	19°18'	14°52'	14°29'
Yr. of construction	1930	1963	1969	1984	1989	1986	1958	1964	1988
Elevation (m) MSL	95.8	196.6	179.8	269.7	523.6	280.5	213.4	365.7	100.6
Bed level (m) MSL	77.2	181.3	73.1	167.6	500	258.6	185	335.3	67.1
Max. depth (m)	18.6	15.3	106.7	102.1	23.6	21.9	28.4	30.4	33.5
Mean depth (m)	3.9	5.2	40.5	14.2	5.1	8.4	8.9	8.5	10.3
Area at FRL (ha)	1626	2507	28474	61404	16534	8103	2474	1703	21349
Catchment (km^2)	707	9056	215194	205247	16035	6475	2580	1354	48645
Area : Catchment	43	361	756	334	97	80	104	79	228
Av. Area (ha)	1074	1400	18429	33689	8700	4833	1842	889	12695
Capacity (10^6 m^3)	64.7	130.3	11560	8721	849.5	680.6	215.3	146.1	2208.4
Annual inflow (10^6 m^3)	193.7	87.7	42358	36449.9	595.8	661	773.1	373.8	2562.5
Flushing rate	3	0.7	3.7	4.2	0.7	1	3.6	2.5	1.2
Shore dev. index	5.6	3.6	7.9	12.9	8.4	4.7	8	3.5	
Volume dev. index	0.64	1.02	1.14	0.42	0.66	0.94	0.95	0.84	0.73

varied from 43 (Wyra) to 756 (N.sagar). Srisailam (334), Musi (361), Somasila (224) and Kadam (104) also have fairly high ratios. In Nagarjunasagar and Srisailam much of the catchment has been intercepted by dams in the upstream.

The storage capacity of N.sagar is the highest in the country at 11560 x 10^6 m^3 followed by Srisailam 8721 x 10^6 m^3. Lowest is Wyra with 64.7 x 10^6 m^3. The flushing rate (annual inflow/ storage capacity) is high in Srisailam at 4.9 followed by N.sagar (3.7), Kadam (3.6) and Wyra (3.0) and low in Somasila (1.0), Singur (0.7) and Musi (0.7). The annual inflow and flushing rate have positive effect on the productivity of the reservoir as they have a direct bearing on the loading of organic matter and nutrients.

The shore development index (SDI) which indicates the degree of irregularity of the shoreline is higher in Srisailam (12.9), Singur (8.4) and Kadam (8.0). In others it varied from 3.5 (MPD) to 7.9 (N.Sagar). The SDI index shows that the shore lines of Srisailam, Singur, Kadam, N.Sagar are highly irregular forming coves and bays.

The volume development index (VDI) is indicative of the nature of basin wall towards water, being more than 1 in cup shaped basins (basin wall concave towards water) and less than 1 in saucer shaped water bodies (basin wall convex towards water). Except for N.Sagar and Musi, VDI is less than unity in all other reservoirs.

Considering the morphometric and hydrological characteristics, Srisailam, Kadam and Wyra could be considered as more productive reservoirs. Musi receives industrial effluents and city sewage from Hyderabad. With low flushing rate the reservoir is polluted with fish kills occurring often.

Chemical characteristics of soil

Table 2 depicts chemical characteristics of soil. It is remarkable that the soil in all the reservoirs is alkaline with pH in the range 7.2 (Musi) to 8.1 (Somasila). Available N (mg/100g) ranged between 27.1 (Somasila) and 86.2 (Musi). Wyra (62.8), LMD (55.0), MPD (55.1) and N.Sagar (50.4) also showed relatively higher values of available nitrogen, while Singur (36.0) and Srisailam (27.4) had low levels. Available phosphorus of soil was extremely low and was in detectable quantity only during post-monsoon season. The nutrient status of soil do not give any indication of the production levels of reservoirs. The organic load in Musi is reflected in the high level of available nitrogen.

Table 2. Chemical characteristics of soil in reservoirs of A.P.

	Wyra	Musi	N.Sagar	Srisailam	Singur	LMD	Kadam	MPD	Somasila
pH	7.9	7.2	7.5	7.5	7.8	7.9	7.8	7.6	8.1
Org. Carbon (%)	1.15	3.86	2.49	2.49	0.94	1.86	1.94	1.73	0.58
Free $CaCO_3$ (%)	12.58	14.17	6.12	6.12	7.08	4.58	6.00	4.31	5.65
Avail. N (mg/100 g)	62.8	86.2	50.4	50.4	27.4	55.0	44.2	55.1	27.1
Avail. P (mg/100 g)	Tr - 0.2	Tr - 0.6	Tr - 0.6	Tr - 0.2	Tr - 0.28	Tr - 0.25	Tr - 0.3	Tr - 0.25	Tr - 0.2
Total N (%)	0.107	0.181	0.181	0.090	0.084	0.089	0.072	0.102	0.069
C/N Ratio	10.8	32.5	32.5	22.0	17.8	21.3	26.4	15.5	8.3

Free $CaCO_3$ was very high in Musi (14.17%) and Wyra (12.58%). In other reservoirs it varied from 4.31% (MPD) to 7.08% (Srisailam).

Organic carbon of soil was high in all the reservoirs, especially in N.Sagar (2.49%), Kadam (1.94%), LMD (1.86%) and Singur (1.7%). Musi had unusual level at 3.86% owing to the pollutants. Going by organic carbon content of the soil all the reservoirs have fairly high level of productivity with Kadam, LMD, Singur,Wyra and N.Sagar showing higher levels.

Nitrogen mineralisation and immobilisation in sediments is governed by the C/N ratio. Higher the ratio (> 20) higher is the immobilisation of inorganic N as compared to low ratio (< 10) which is favourable for mineralisation of organic N making it in readily available form in water. C/N ratio in the range of 8.3 to 17.8 in Somasila, Wyra, Srisailam, MPD and Singur, indicate higher productivity in these reservoirs. Higher C/N ratio were observed in LMD, Kadam and N.Sagar (21.3 to 26.4) due to high organic load from the catchment area. The highest ratio (32.5) in Musi is in keeping with the high organic load it receives from the city sewage.

Water quality

Physical features

Water quality in terms of physical and chemical features is depicted in Table 3. The reservoirs being situated in the lower latitudes have little seasonal variation in the temperature. There is no significant variation in water temperature of different reservoirs. The mean surface water temperature ranged between 27.3 to 29.5°C in the overall range of 25.5 to 32.0°C. The mean transparency ranged between 70 (Musi) to 198 cm (N.sagar). Most of the reservoirs showed clear water with mean transparency above 1 m showing the euphotic zone to be above 2 m throughout the year. High turbidity during monsoon was observed only in Wyra, Musi and Somasila.

Chemical features

pH : The reservoirs under study are all alkaline with mean pH ranging between 8.3 to 8.8. There is no marked variation in pH of reservoirs of different drainages. pH values were higher during pre-monsoon months reaching 9.9 in Wyra, 9.8 in Musi and Kadam. The values were around 8.0 in monsoon months.

Table 3. Physico-chemical characteristics of water (mean & range) in reservoirs of A.P.

	Wyra	Musi	N.Sagar	Srisailam	Singur	LMD	Kadam	MPD	Somasila
Temp (°C)	**29.4** 29.0-30.1	**29.3** 29.5-30.0	**28.7** 28.5-30.0	**28.2** 28.5-28.8	**27.3** 25.5-29.0	**29.5** 28.0-32.0	**29.3** 28.5-30.5	**27.9** 28.8-30.0	**29.5** 29.0-31.0
Transp. (cm)	**74** 42-120	**70** 40-90	**198** 195-200	**136** 130-142	**136** 100-180	**145** 120-177	**100** 100-140	**128** 95-170	**93** 40-140
pH	**8.8** 8.2-9.9	**8.8** 8.1-9.8	**8.7** 8.4-8.8	**8.3** 7.9-8.8	**8.6** 8.0-9.2	**8.7** 8.3-9.2	**8.8** 7.9-9.8	**8.5** 8.1-8.9	**8.4** 8.1-8.5
DO (mg/l)	**6.8** 6.4-7.6	**8.0** 6.4-10.0	**8.4** 8.0-8.8	**8.0** 7.2-8.6	**7.3** 6.8-7.6	**7.5** 6.8-8.0	**8.0** 7.1-9.6	**7.6** 7.4-7.8	**7.2** 6.8-7.4
CO_3 (mg/l)	**24** 16-28	**37** 32-40	**17** 12-24	**27** 16-32	**24** 16-40	**27** 16-38	**27** 16-40	**15** 4-24	**14** 4-24
HCO_3 (mg/l)	**170** 136-190	**188** 164-180	**95** 84-104	**80** 68-88	**108** 76-128	99 90-108	**123** 108-132	**80** 48-104	**111** 96-140
TA (mg/l)	**194** 152-218	**225** 196-260	**112** 96-128	**107** 100-120	**132** 116-144	**126** 124-128	**150** 146-156	**95** 64-112	**125** 100-156
Cond. (U mhos cm)	**610** 400-810	**1240** 970-1650	**516** 440-570	**543** 430-700	**333** 280-390	**383** 320-420	**406** 330-490	**316** 220-390	**553** 320-830
TDS (mg/l)	**365** 260-526	**806** 630-1072	**335** 286-370	**352** 279-455	**216** 182-253	**249** 208-266	**264** 214-318	**206** 143-253	**360** 208-539
Ca++ (mg/l)	**40** 21-58	**39** 29-55	**27** 26-28	**25** 21-29	**26** 17-32	**22** 18-24	**25** 22-27	**19** 16-21	**22** 18-26
Mg++ (mg/l)	**13.2** 8.7-21.4	**21.0** 17.5-26.2	**9.7** 7.7-10.7	**9.5** 8.2-10.7	**11.1** 9.2-13.4	**11.6** 10.6-14.1	**15.4** 10.7-18.4	**7.8** 4.8-9.7	**8.5** 6.8-11.6
Hardness (mg/l)	**139** 96-182	**183** 152-210	**107** 100-112	**102** 92-108	**112** 98-124	**102** 100-104	**124** 112-132	**80** 60-92	**91** 72-108
Chloride (mg/l)	**47** 42-54	**240** 153-341	**46** 37-57	**48** 37-54	**16** 14-20	**28** 23-31	**21** 11-31	**28** 17-43	**92** 45-162

(Mean values in bold figures)

Free CO_2 and DO : Free carbon dioxide was never recorded in any reservoir at surface. Dissolved oxygen was in the range 6.8 to 8.4 mg/l. Higher values were recorded in Musi during March probably due to *Microcystis* bloom. In general higher concentration of DO occurred during pre- and post-monsoon months. The values in general were lower during monsoon probably due to turbidity.

Alkalinity : Alkalinity, the acid combining capacity of natural fresh waters is generally caused by the carbonates and bicarbonates of calcium and magnesium. The reservoirs under study are all alkaline with total alkalinity above 100 mg/l except in MPD (95 mg/l). Higher values were recorded in Musi (255 mg/l) (reservoir receiving city sewage), Wyra (194 mg/l) and Kadam (150 mg/l) (old impoundments belonging to different watersheds). Higher values occurred during pre-monsoon months due to reduced water levels and concentration of ions and lower values in monsoon season due to dilution.

It is widely mentioned that lakes with total alkalinity around 100 mg/l and above show higher productivity and by this yard stick all the reservoirs under study are productive with high fish yield potential.

Carbonates and bicarbonates which contributed to total alkalinity followed more or less similar trend of total alkalinity in seasonal variation. Bicarbonates ranged from 80.0 (MPD) to 188 mg/l (Musi). Reservoirs with relatively higher HCO_3 are Musi (188 mg/l), Wyra (170 mg/l), Kadam (123 mg/l), Somasila (111 mg/l) and Singur (108 mg/l). Carbonates ranged between 14 (Somasila) and 37 mg/l (Musi).

Conductivity and TDS : The two positive correlates of total alkalinity, the conductivity and TDS, showed similar trend in seasonal distribution as that of alkalinity in different reservoirs. As Musi is subjected to anthropogenic stresses, the conductivity (1240 μ mhos/cm) and TDS (806 mg/l) values were very high. Higher ionic concentration (μ mhos/cm) was also recorded in Wyra (610), Somasila (553), Srisailam (543) and N.sagar (516). MPD (316) and Singur (333) had relatively low concentration of ions. Higher concentration of ions in Somasila than MPD, the reservoir of the same drainage, is atrributable to the inflows it receives from Srisailam reservoir through Telugu Ganga Canal.

Barring Musi which showed unusally high values, the TDS in other reservoirs ranged from 206 (MPD) to 365 mg/l (Wyra). Somasila , Srisailam, N.sagar had TDS between 300 and 350 mg/l.

A full view of Mid Pennar Dam

Study of benthic organisms

An assorted fish catch from Mid Pennar Dam

Calcium, magnesium and hardness : Calcium ion was rich in Wyra with mean value at 40 mg/l followed by Musi (39 mg/l) and the lowest was in MPD (19 mg/l). In others it ranged between 22 and 27 mg/l. Magnesium, an important component of chlorophyll which also contributes to the hardness of water, was the high in Musi (21 mg/l) and in others it occurred in the range 7.8 (MPD) to 15.4 mg/l (Kadam). Calcium and magnesium occurred in good concentration which promotes productivity in all the reservoirs under study. Total hardness reflected the trends of calcium and magnesium in different reservoirs. It was in the range 80 (MPD) to 183 mg/l (Musi).

Chloride : High values of chloride was recorded in Musi at 240 mg/l indicating the pollution conditions prevailing in the reservoir. Somasila also showed relatively higher concentration of chlorides at 90 mg/l. In others it ranged from 16 (Singur) to 48 mg/l (Srisailam).

Nutrient features

Nitrates and phosphates : The importance of nitrogen and phosphorus as essential nutrients for the productivity of lakes, has been well recognized. A concentration of 0.2 to 0.5 mg/l of inorganic nitrogen and 0.05 to 0.2 mg/l of phosphorus have been considered to be favourable for productivity. In all the reservoirs under study the concentration of nitrogen and phosphorus are rather poor (Table 4). Nitrate nitrogen was in traces during most part of the year. However the level of NO_3-N improved during post- monsoon months to the extent of 0.56 (Kadam) to 0.86 mg/l (N.Sagar) and it appears to get dissipated quickly in the system.

PO_4-P was also recorded in traces in pre-monsoon and monsoon months. However in post- monsoon months it was recorded in the range 0.01 to 0.02 mg/l in different reservoirs.

Silicates : The concentration of silicates (SiO_2) appear to be normal with the average in the range 6.4 (Somasila) to 13.9 mg/l (Kadam). Reservoirs with fairly high concentration of silicates, besides Kadam, are Wyra (11.8), Singur (9.2), Musi (8.9) and N. Sagar (8.8).

As can be seen, the nutrients are in low concentration in all the reservoirs. The probabilities for such low values could be either quick turnover of these elements as recorded in tropical water bodies or their loading from the catchment is of low order. However, in Indian reservoirs essential nutrients are generally poor and cannot be relied

Table 4. Nutrient concentration of water (mg/l) in reservoirs of A.P.

Reservoir	NO_3-N	PO_4-P	SiO_2-Si
Wyra	Tr-0.68	Tr-0.01	**11.8** 7.6-16.8
Musi	0.07-0.82	Tr-0.02	**8.9** 4.4-12.2
N. Sagar	Tr-0.86	Tr-0.01	**8.8** 7.2-9.8
Srisailam	Tr-0.60	Tr-0.02	**7.9** 6.6-9.0
Singur	Tr-0.82	Tr-0.02	**9.2** 6.0-11.4
LMD	Tr-0.74	Tr-0.01	**8.5** 7.2-9.6
Kadam	Tr-0.56	Tr-0.01	**13.9** 9.4-16.8
MPD	0.05-0.62	Tr-0.02	**7.8** 4.4-10.6
Somasila	Tr-0.60	Tr-0.02	**6.4** 4.8-8.6

Bold figures indicate mean values

Dam site view of
Somasila Reservoir

Fish catch of Somasila Reservoir

Scientific investigation in Somasila Reservoir upon as indices of productivity. Many of the reservoirs with low nutrient status were found to be productive. This could be due to the fact that the organic matter of allochthonous origin plays greater role in reservoir productivity.

Depth-profile distribution of physico-chemical parameters

Thermal stratification

Water temperature did not show any remarkable variation from surfce to bottom. Even in deep reservoirs like N.sagar and Srisailam the variation in temperature was of the order of 3 to 5°C in pre-monsoon and post-monsoon. In shallow reservoirs it was 1°C in Wyra, 1.5°C in Musi, 1.0°C in Singur, 2.2°C in LMD, 2.5°C in Kadam, 2.8°C in MPD and 1.8°C in Somasila during summer. In monsoon months almost isothermal conditions prevailed in the water column. In reservoirs of seasonless tropics thermal stratification is generally non-existent. Even if it occurs during summer it remains ephemeral.

Chemical stratification

Chemical stratification generally occurs in reservoirs during pre- and post-monsoon months. DO, pH, alkalinity and nutrients show variation with depth in different seasons. The strength of chemical stratification provides an useful clue to the productivity status of reservoirs. Among chemical parameters, oxygen profile with depth (Oxycline) is the most dependable index of productivity. Productive reservoirs show steep oxycline with almost anoxic conditions at the bottom during summer.

In reservoirs under study oxycline (Fig. 2a to 2d) is particularly steep in LMD, Kadam, MPD, Srisailam and these could be categorised as productive reservoirs. In Musi almost anoxic conditions prevailed at 8 m depth due to the organic load it receives.

Alkalinity showed an increasing trend in pre-monsoon months exhibiting clinograde distibution which was well marked in Kadam, Srisailam and LMD. However, in some others it showed a reverse trend. pH showed a decreasing trend with depth, but the variation was not very remarkable and it was 1 in LMD and less than 1 in other reservoirs.

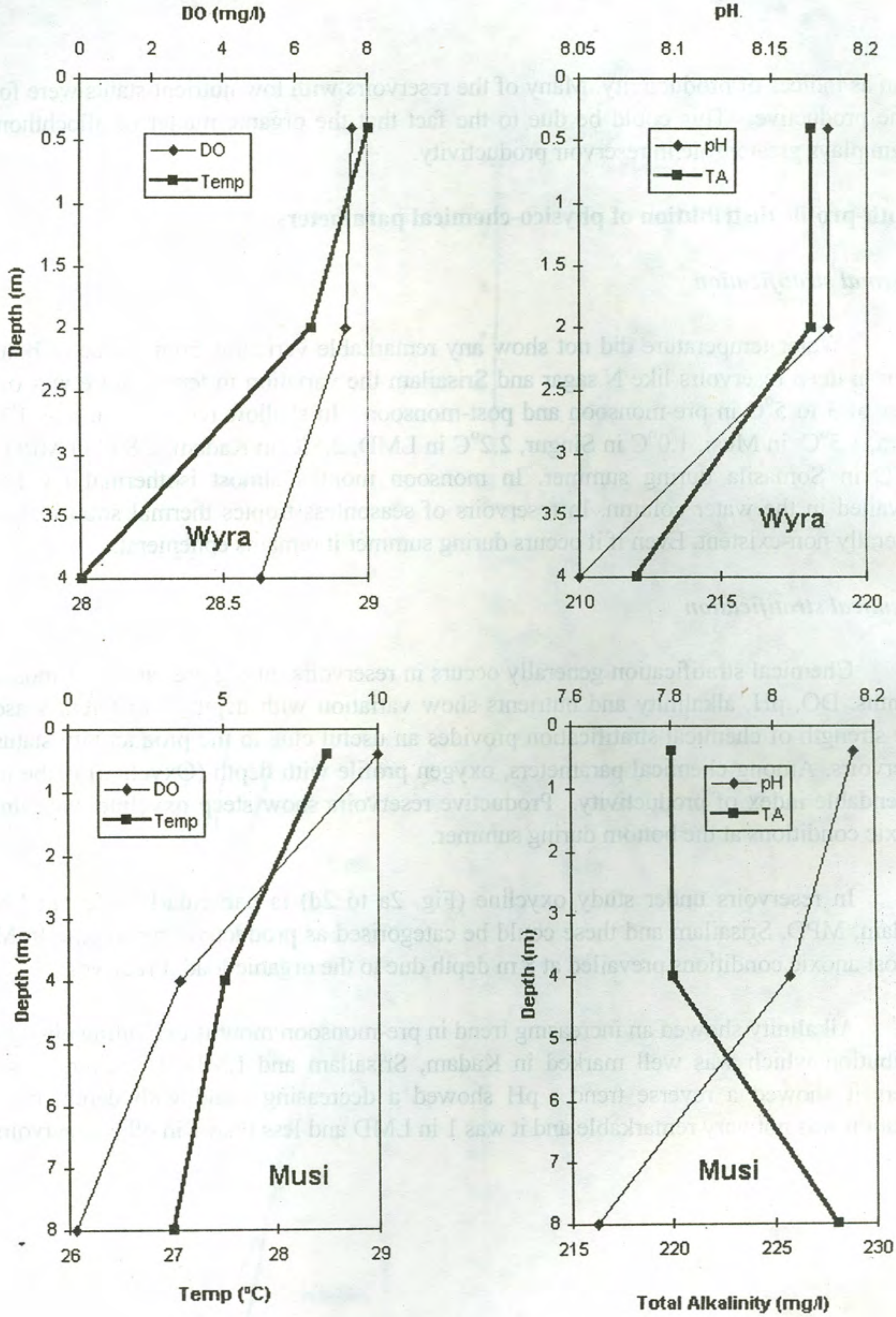


Fig 2a. Stratification in reservoirs of A.P.

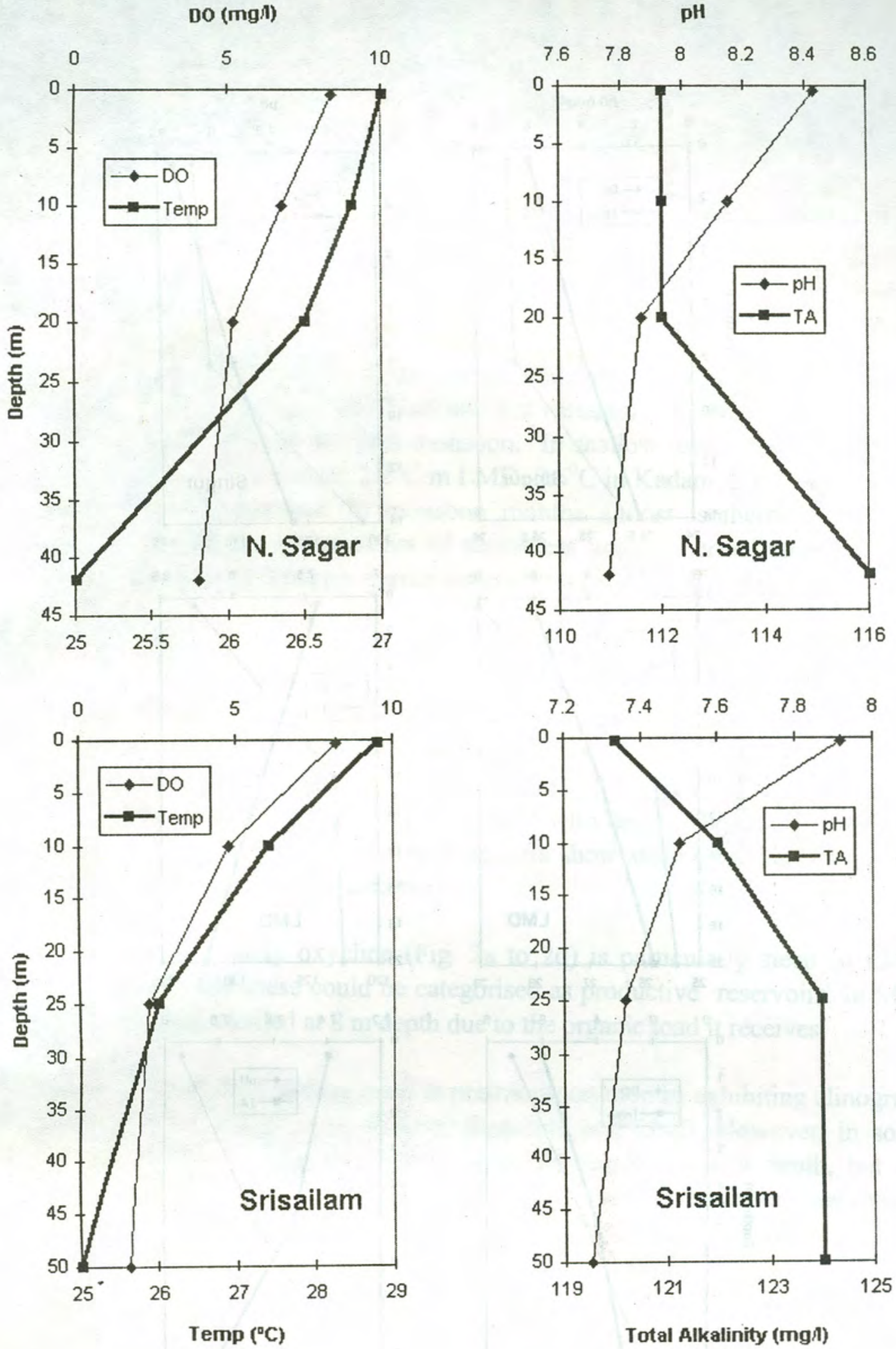


Fig 2b. Stratification in reservoirs of A.P.

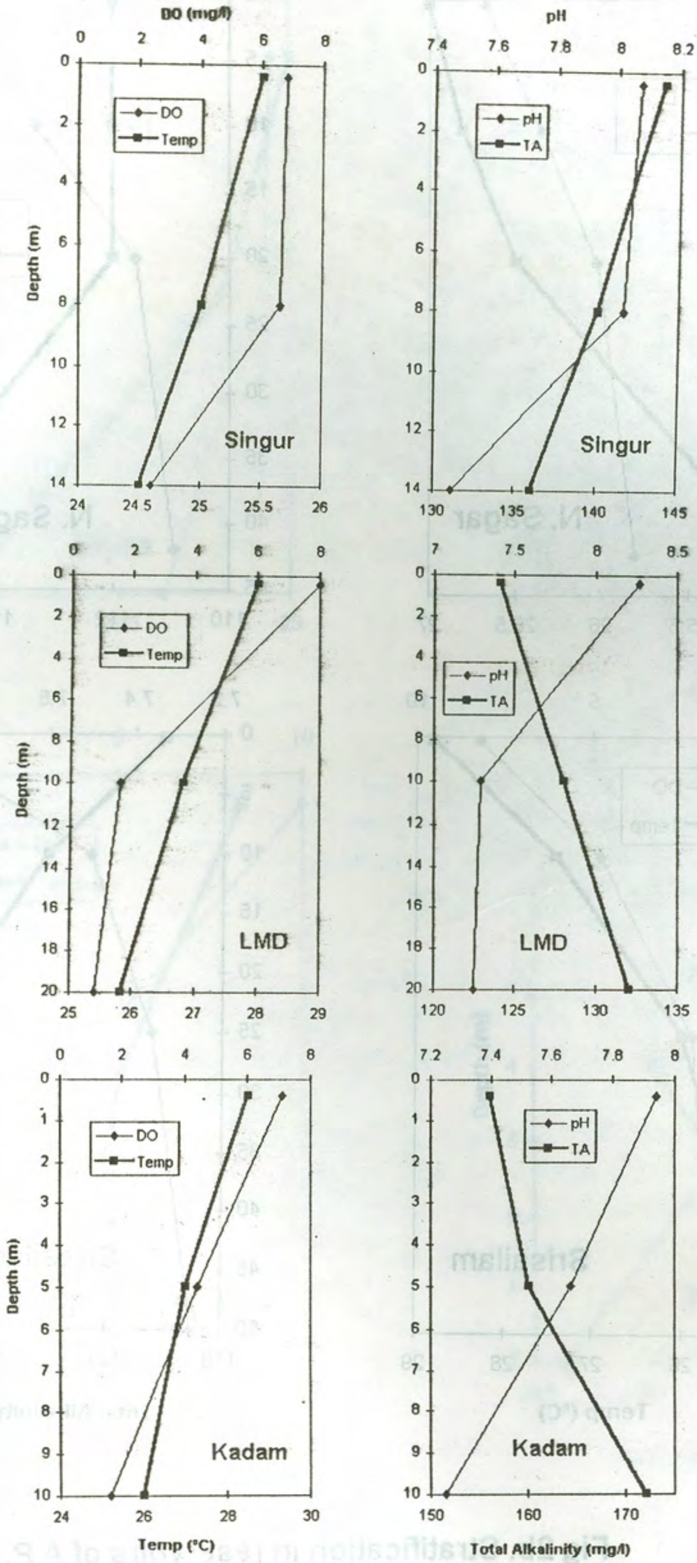


Fig 2c. Stratification in reservoirs of A.P.

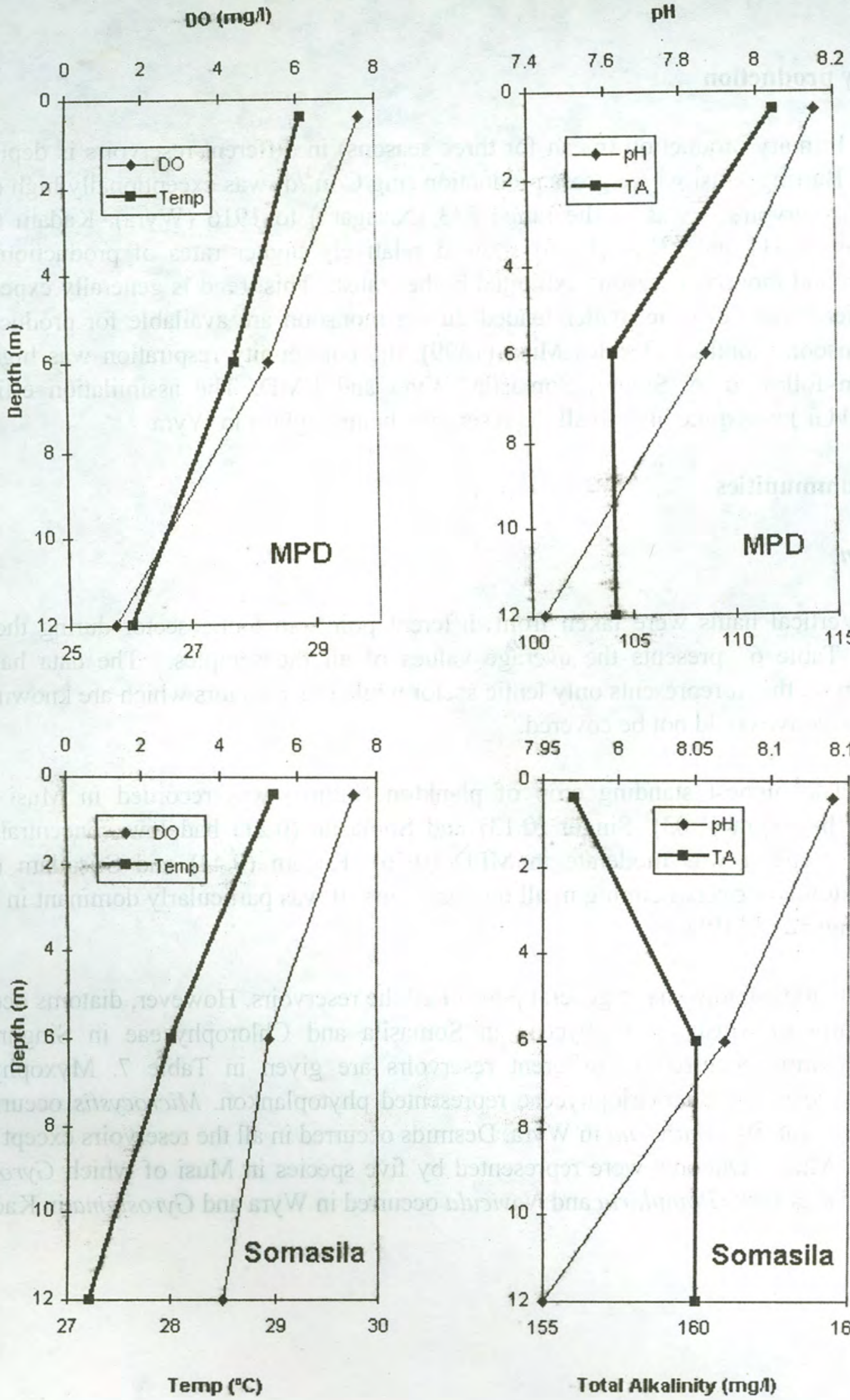


Fig 2d. Stratification in reservoirs of A.P.

Primary production

Primary production (mean for three seasons) in different reservoirs is depicted in Table 5. Barring Musi where gross production (mg $C/m^3/d$) was exceptionally high (6094), in other reservoirs it was in the range 833 (N.sagar) to 1916 (Wyra). Kadam (1383), Srisailam (1371) and MPD (1106) showed relatively higher rates of production. Post-monsoon and monsoon seasons exhibited higher rates. This trend is generally expected as the nutrients and organic matter loaded during monsoon are available for production in post-monsoon months. Besides Musi (1399), the community respiration was highest in Srisailam followed by Singur, Somasila, Wyra and LMD. The assimilation efficiency (NPx100/GP) was quite high in all the reservoirs being highest in Wyra.

Biotic communities

Plankton

Vertical hauls were taken from different points in lentic sector during the three seasons. Table 6 presents the average values of all the samples. The data have the limitation in that it represents only lentic sector while other sectors which are known to be more productive could not be covered.

The highest standing crop of plankton (ml/m^3) was recorded in Musi (2.08) followed by Wyra (1.03). Singur (0.13) and Somasila (0.21) had low concentration of plankton while it was moderate in MPD (0.76), Kadam (0.44) and Srisailam (0.41). Zooplankton was overwhelming in all the reservoirs. It was particularly dominant in Wyra, Musi, Singur and MPD.

Phytoplankton was in general poor in all the reservoirs. However, diatoms occurred significantly in Musi, Myxophyceae in Somasila and Chlorophyceae in Singur. The plankton forms occurred in different reservoirs are given in Table 7. Myxophyceae, Chlorophyceae and Bacillariophyceae represented phytoplankon. *Microcystis* occurred in Musi and Somasila, *Anabaena* in Wyra. Desmids occurred in all the reservoirs except in the eutrophic Musi. Diatoms were represented by five species in Musi of which *Gyrosigma* was more prevalent. *Pinnularia* and *Navicula* occurred in Wyra and *Gyrosigma* in Kadam.

Limnological investigation in Reservoir

An assorted fish catch from Singur Reservoir

Table 5. Primary production (mg C/m^3/d) in reservoirs of A.P.

Reservoir	GP	NP	Respiration	% of NP in GP	% of respiration in GP
Wyra	1916	1583	383	80.3	25.0
Musi	6094	4928	1399	81.7	21.9
N. Sagar	833	583	300	69.4	36.6
Srisailam	1371	879	675	64.2	40.3
Singur	1000	639	433	63.5	43.8
LMD	950	642	370	64.8	42.2
Kadam	1383	1137	296	80.8	23.0
MPD	1106	807	359	72.2	33.3
Somasila	1058	708	420	64.7	42.3

GP - Gross production, NP - Net production

Table 6. Plankton abundance (No/l) in reservoirs of A.P.

	Wyra		Musi		Srisailam		Singur		LMD		Kadam		M.P. Dam		Somasila	
	No	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*	*No*	*%*
Vol. ml/m^3	**1.03**		**2.08**		**0.41**		**0.13**		**0.33**		**0.44**		**0.76**		**0.21**	
Phytoplankton																
Myxophyceae	22	5.41	16	2.4	-	-	-	-	10	8.77	-	-	-	-	29	12.89
Chloro-phyceae	6	1.47	21	3.15	12	7.89	24	8.28	2	1.75	6	3.37	32	5.72	10	4.44
Bacillario-phyceae	27	6.63	63	9.45	-	-	-	-	-	-	3	1.69	-	-	-	-
Zooplankton																
Protozoa	22	5.41	5	0.75	11	7.24	1	0.34	4	3.51	1	0.56	19	3.4	6	2.67
Rotifera	40	9.83	67	10.04	12	7.84	63	21.72	6	5.26	32	17.98	102	18.25	25	11.11
Cladocera	179	43.98	300	44.98	33	21.71	117	40.34	41	35.96	64	35.96	194	34.7	81	36
Copepoda	111	27.27	195	29.23	84	55.27	85	29.32	51	44.75	72	40.44	212	37.93	74	32.89
Total Plankton	407		667		152		290		114		178		559		225	

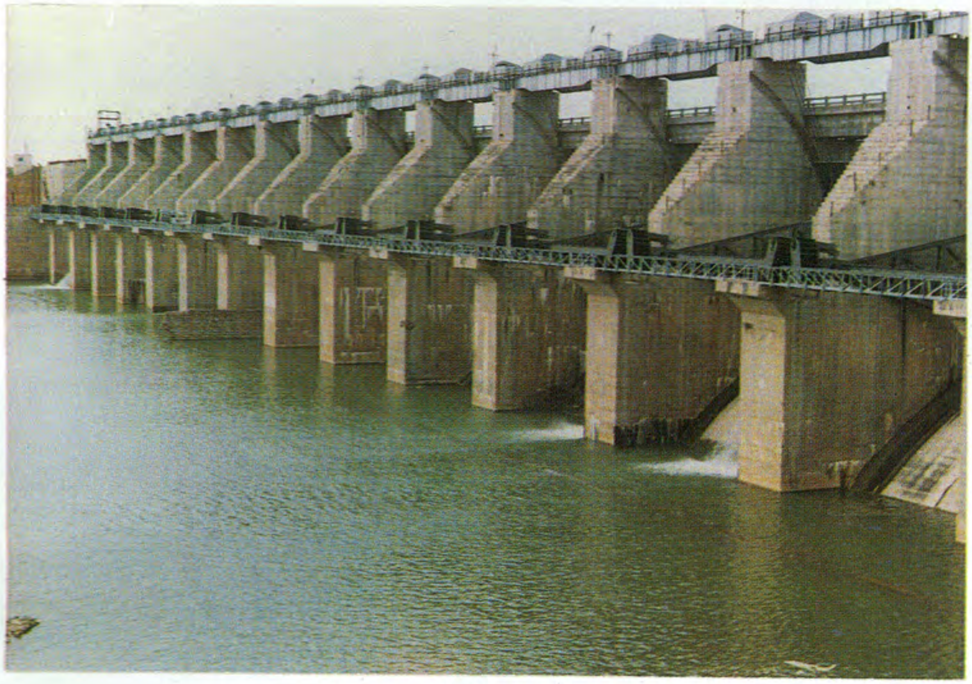
Table 7. Plankton forms encountered in reservoirs of A.P.

	Wyra	*Musi*	*N. Sagar*	*Srisai-lam*	*Sin-gur*	*LMD*	*Ka-dam*	*MPD*	*Soma-sila*
Myxophyceae									
Microcystis		p	p			p			p
Anabaena	p		p						
Spirulina		p							
Chlorophyceae									
Ulotorix		p			p		p	p	
Desmidium	p		p	p	p	p	p	p	p
Cosmarium			p						
Gonatozygon								p	
Bacillariophyceae									
Fragilaria		p	p						
Pinnularia	p	p							
Nitzschia			p						
Navicula	p	p	p						
Synedra		p	p						
Gyrosigma		p							
Protozoa									
Arcella	p	p		p	p	p	p	p	p
Centropyxis	p					p			

Table 7 ...... contd. /-

Rotifera

Keratella		p	p	p				p	p
Brachionus	p	p	p	p	p	p	p	p	p
Testudinella				p				p	
Lecane						p			
Filinia							p		
Polyarthra								p	
Conochilus			p						
Cladocera									
Bosmina	p	p	p	p	p	p	p		p
Alona	p		p		p		p	p	
Ceriodaphnia			p						
Polyphemus	p	p	p	p	p		p	p	p
Leptodora								p	
Chydorus	p								
Simocephalus					p				
Moina	p	p	p	p	p	p	p	p	p
Daphnia	p	p	p	p	p			p	p
Copepoda									
Diaptomus	p	p	p	p	p	p	p	p	p
Cyclops	p	p	p	p	p	p	p	p	p



A view of Singur Dam

Limnological sampling in Singur Reservoir

Protozoa, Rotifera, Cladocera and Copepoda represented zooplankton . Copepoda and cladocera constituted the bulk of zooplankton. Among Copepoda, calanoid copepods (*Diaptomus*) were prevalent followed by cyclopoids (*Cyclops*) along with their nauplii. Cladocera was however, represented by several species of which *Bosmina, Diaphanosoma* and *Moina* were important. Musi, Wyra, Singur and Somasila showed significant densities of cladocerans. *Brachionus* was the most dominant form representing Rotifera which occurred in all the reservoirs. It was particularly significant in Musi, Wyra and Kadam.

Arcella is the common species of protozoa occurring in all the reservoirs.

Reservoirs with rich zooplankton populations in the stated order of abundance are Musi, MPD, Wyra, Singur, Somasila, Kadam and Srisailam. It is significant that relatively shallow reservoirs had higher concentration of zooplankton.

Bottom macrofauna

The standing crop (organisms/m^2) of macrobenthos was richest in Musi (3958) followed by MPD (2270), Kadam (2149) and Wyra (1121). Singur and LMD showed moderately rich crop while it was poor in N.sagar, Somasila and Srisailam (Table 8). The situation in N. Sagar, Somasila and Srisailam is not truly reflected in the present studies as the sampling was restricted to lentic sector which is deep and characterised by poor benthos. The bays and intermediate sectors which generally harbour rich benthos could not be sampled. The old and shallow reservoirs were richer than deep and new impoundments.

The concentration of benthos was maximum in post-monsoon and pre-monsoon months. Dipteran larvae (*Tendipes, Chaoborus* and others), molluscs (gastropods and bivalves) constituted bulk of the biota in different reservoirs. Other groups that occurred at low density were oligochaetes, trichopterans and coleopterans.

Musi, MPD, Singur and Wyra had high cncentration of chironomid larvae. Kadam, Musi and Wyra also had rich populaton of dipteran larvae. The high organic deposits at the bottom with frequent low levels of DO in these reservoirs favoured these species. Molluscs were predominant in Singur, Somasila, Srisailam and to some extent in MPD and Kadam. The molluscan dominance in N. Sagar as revealed in earlier studies has not reflected in the present study due to reasons stated before.

Table 8. Bottom biota (No. of organisms/m^2) in reservoirs of A.P.

	Wyra	Musi	N. Sagar	Srisailam	Singur	LMD	Kadam	MPD	Somasila
Tendipes larvae	288	2990	20	-	347	515	69	2136	54
Chaborus larvae	23	26	2	-	11	2	221	35	-
Other Dipteral larvae	750	896	21	-	21	17	1786	20	11
Gastropods	39	44	49	222	324	32	69	74	258
Bivalves	8	-	30	-	29	-	4	-	5
Oligochaetes	8	2	1	-	6	-	-	5	-
Trichopteran larvae	-	-	-	8	-	-	-	-	2
Coleopteran larvae	5	-	-	-	-	-	-	-	-
Total no/m^2	1121	3598	123	230	740	566	2149	2270	330
Total wt. (g/m^2)	61.0	7.8	8.0	-	52.0	26	5.6	48.0	45.2

In terms of benthic fauna, MPD, Kadam and Wyra could be considered as high productive reservoirs followed by Singur and LMD.

Fishing effort

Almost all the reservoirs are being exploited through licencing system. The number of licences issued and the craft and gear employed in different reservoirs are given in Table 9. Coracles and thermocole rafts are the craft employed. In reservoirs of coastal A.P. and Rayalseema districts (Somasila, MPD, Srisailam and N. Sagar) coracles are popular while in reservoirs of Telangana region (Wyra, Musi, Singur, Kadam and LMD) thermocole rafts are commonly employed. Gillnets are the dominant gear followed by castnets, shore seines and traps. Traps and castnets are predominantly used in the shallow Wyra reservoir to exploit the prawn, *M. malcolmsonii*. There appears to be no mesh regulation in many reservoirs. Small meshed gillnets of 1.2 to 4.0 cm are being used in severeal reservoirs. Only in Srisailam the minimum mesh size is quite high at 12.5 cm. From the records it shows that all the reservoirs are being well exploited.

Fish catch and species composition

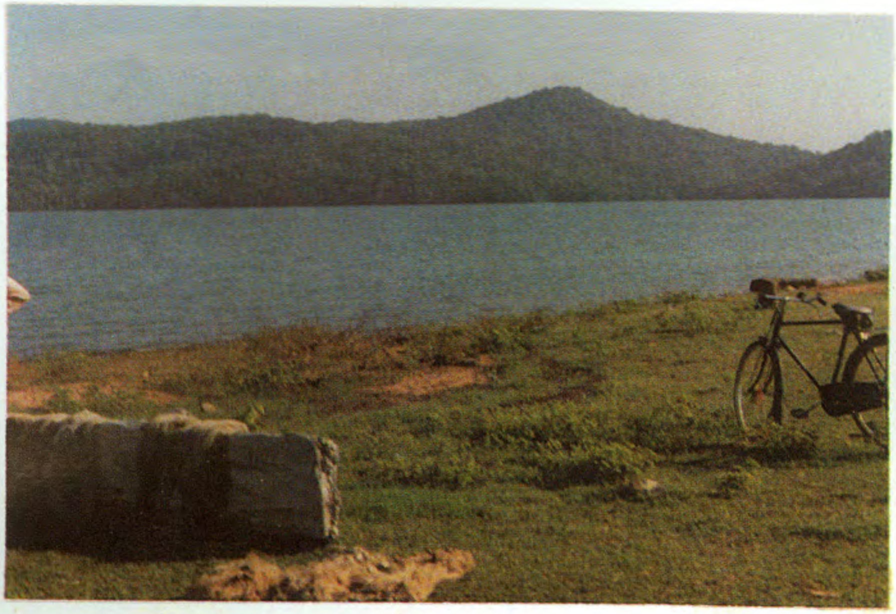
There is no agency monitoring the catch at any of the reservoirs. As the present survey was confined to short visits during the three seasons, it was not possible to estimate the annual catch. In some reservoirs fishing was suspended during monsoon months and in some reservoirs it was not possible to cover all the landing centres in the limited time available for sampling. The fishes occurred in commercial catches of different reservoirs are given below.

Wyra reservoir

The prawn, *Macrobrachium malcolmsonii* contributed about 50% to the catch. Among fishes, major carps *C. catla* and *L. rohita* accounted for about 40% and the rest were catfishes. Catla occurred at a modal length of 325 mm (0.5 kg) and rohu 390 mm (0.55 kg). Catfishes were *M. aor, M. cavasius* and *O. bimaculatus*. The major carps appear to belong '0' age group.

Table 9. Fishing effort in selected reservoirs of A.P.

Reservoir	No. of licences	Coracles	Rafts	Gill nets			Cast nets		Traps	Seins
				Units	*Length of each unit (m)*	*mesh (cm)*	*No.*	*Mesh*		
Somasila	1500	1500	-	1500	150-200	7.5-37.5	-	-	-	10
M.P. Dam	101	101	-	200	300-500	5.0-30.0	40	-	100	2
Srisailam	1250	1250	-	1250	400-500	12.5-30.0	-	-	-	-
Musi	1200	15	1200	1200	500-750	1.2-30.0	100	1.2-25.0	-	11
Wyra	600	-	600	550	400-800	2.5-25.0	600	1.0-15.0	600	-
Singur	226	-	226	226	300-500	4.0-12.0	-	-	-	-
Kadam	500	-	500	500	200-400	-	250	4.0-8.0	-	10
L.M. Dam	500	-	500	500	50-150	3.0-12.0	-	-	-	-



A view of the lentic sector of Kadam Dam

Harvesting of Indian Major Carp from Kadam Dam

Musi reservoir

Carps were observed to form about 52% of the catch. *C. catla* occurred in the range 370 to 610 mm (1.0 to 4.0 kg), *L. rohita* between 412 and 540 mm (0.95 to 2.0 kg). Among minor carps, *P. sarana* showed a single mode at 230 mm (0.125 kg). Others were *W. attu* (600-840 mm; 1.5 - 4.0 kg), *N. notopterus* (225-280 mm; 0.15-0.2 kg) and *O. bimaculatus* (mode 270 mm) and the prawn *M. malcolmsonii* (140-190 mm, 5.0-100 g).

Singur reservoir

Major carps were represented by *L. rohita* and *C. mrigala*; the former occurred in the range 178-510 mm (0.1-2.0 kg) and the latter from 320-465 mm (0.45-1.0 kg). Other fishes in the catch were *M. aor, M. seenghala, N. notopterus, O. bimaculatus* and *M. armatus*.

Lower Manair Dam

About 60% of the catch was constituted of carps represented by *C. catla* (372 mm), *L. rohita* (283-530 mm) and *L. calbasu* (400-445 mm). Others were *M. seenghala, O. bimaculatus, C. batrachus, P. sarana, Channa* spp. and *Anabas* sp.

Kadam reservoir

About 55% of the catch comprised of carps represented by *L. rohita* 310-595 mm (0.5-2.5 kg), *L. calbasu* 252-452 mm (0.3 - 1.5 kg). *T. khudree, P. sarana* and *C. reba*. Others were *W. attu, M. seenghala, N. notopterus, O. bimaculatus* and *M. corsula*.

Srisailam reservoir

During monsoon and post monsoon months the catches composed of major carps only. *C. catla* occurred at a modal length of 740 mm (7.75 kg), *L. rohita* at 600 mm (3.0 kg) and *C. mrigala* at 550 mm (2.0 kg).

Mid Penna Dam

About 35% of the catch comprised carps represented by *C. catla* (930 mm, 15.0 kg) *L. rohita, L. potail* and *P. kolus*. Others were *M. seenghala, M. aor, M. cavasius, O. bimaculatus, N. notopterus, C. punctatus, G. giuris* and *O. cotio*.

Somasila reservoir

About 64% of the catch comprised of carps contributed by *C. catla, L. rohita* (275-365 mm) *C. mrigala* (475-760 mm), *L. calbasu* (380-465 mm). Others were *W. attu* and *O. bimaculatus*.

Nagarjunasagar

Carps formed about 85 to 90% of the catch. The length and weight range of different species in the catch were *C. catla* 480- 805 mm (2.5-8.5 kg), *L. rohita* 275-780 mm (0.23-5.5 kg), *C. mrigala* 470-640 mm (1.25-3.5 kg), *L. calbasu* 370-406 mm (0.55 - 0.9 kg), *M. seenghala* 300-550 mm (0.18-0.94 kg), *O. bimaculatus* 355-375 mm (0.25-0.35kg). *M. aor* 200-480 mm (0.05-0.88 kg), *P. pangasius* 350-470 mm (0.22-0.55), *S. childreni* 380-695 mm (0.4 - 1.7 kg) and *W. attu* 940 mm (4.0 kg).

From the species composition in the fishery, it is apparent that major carps accounted for fairly good proportion in the catches. Obviously stocking has been done in most of the reservoirs, the details of which are not available to study the impact of stocking. The size of catla in the catches of Srisailam, Somasila, MPD indicate good growth of this fish in these reservoirs. Similarly *L. rohita* appears to grow well in Nagarjunasagar, Srisailam and Kadam, *C. mrigala* in Somasila and Srisailam. The performance of *L. rohita* seems to be poor in Somasila, Singur and MPD.

It is rather difficult to arrive at definite conclusion on the fishery based on the meagre sampling during the survey. For instance, during the survey carps accounted for about 85 to 90% of the catch in Nagarjunasagar while during earlier studies, catfishes dominated with *P. pangasius, M. aor, M. seenghala* and *S. childreni* forming substantial proportion of the catches. After the earlier studies, Srisailam reservoir has come up at the head end of Nagarjunasagar. Unlike in Nagarjunasagar where chances for carp breeding are meagre, Srisailam offers excellent breeding conditions in its upper stretches in the inflowing rivers such as Tungabhadra, Hundri, Bhavanasi etc. Whether Srisailam is acting as a recruitment centre for major carps even for Nagarjunasagar to change the fish composition radically is a matter for investigation.

Productivity status of reservoirs

Reservoirs under study are a picture of diversity in terms of their morphometric, drainage, and ecological features. On the basis of area, Wyra, Musi, MPD and Kadam being small impoundments could be considered as productive reservoirs followed by LMD, Singur, Somasila, N.Sagar and Srisailam. If the ratio of catchment to reservoir area (considered to be an index of allochthonous inputs) is to be reckoned then the mainstream reservoirs such as Srisailam, N.Sagar, Somasila and Musi could be placed under productive category followed by Kadam, Singur, MPD, LMD and Wyra. All the reservoirs under study have one or the other positive characters which could place them under productive category.

Among chemical parameters, alkalinity is often taken as the basis for evaluating productivity of lakes. All the reservoirs had total alkalinity around 100 mg/l and above. Musi, Wyra and Kadam have a range of 150-225 mg/l. Based on alkalinity all these could be placed under the category of productive reservoirs. Calcium and magnesium are also in the optimal range. The nutrients such as nitrates and phosphates considered to be essential for production are in low concentration and place the reservoirs under low productive category. However, in Indian reservoirs essential nutrients are always in low concentration even in productive reservoirs and hence are not dependable indices to measure productivity in reservoirs.

The most dependable index indicating reservoir productivity is the strength of oxycline in water column. Strong oxycline in pre-monsoon months was observed in MPD, Kadam, LMD, Srisailam and Singur. Oxycline was less pronounced in Wyra, N. Sagar, Somasila. Wyra being an old and shallow impoundment, strong oxycline is expected. Absence of it could be attributed to the openness of the reservoir without protected bays and the strong pre-monsoon winds. On the basis of oxygen stratification all the reservoirs could be considered productive with the probable exception of Somasila.

The energy transformation of solar energy through primary productivity by chlorophyll bearing organisms gives a dependable parameter for assessing the potential energy resources of the aquatic ecosystems. This method has its limitation in man-made lakes as much of the organic inputs from the allochthonous source are directly utilised and adds to the productivity at primary consumer level. Nevertheless, the pattern of energy flow in different reservoirs gives a glimpse of the efficiency of the systems and their relative productivity status. The efficiency of energy flow and fish producion potential of different reservoirs have been summarised in Table 10. It can be seen that the photosynthetic efficiency is very high in Musi followed by Wyra. Other reservoirs with relatively higher efficiency are Kadam, Srisailam and MPD. The energy at the bottom was maximum in Musi due to the sewage load. Higher bottom energy was also noted in Kadam, LMD, N. Sagar and MPD while it was low in Somasila.

On the basis of carbon assimilation the potential fish production (kg/ha) has been estimated at 159 kg in Wyra, 115 kg in Kadam, 114 kg in Srisailam, 92 kg in MPD, 88 kg in Somasila, 83 kg in Singur, 79 kg in LMD and 69 kg in N.sagar. Wyra ,Kadam and Srisailam are in higher category of production with a potential higher than 100 kg/ha and in others the range being 69 to 92 kg/ha. Under normal exploitation levels 60-70 % of the potentials could be the yield. In all probability the actual yield would be much higher because the allochthonous organic matter contributes substantially to fish yield in reservoirs. No effort has been made to estimate the potential production of Musi as it is a polluted reservoir. Its potential is bound to be substantially higher than all the reservoirs studied.

Guidelines for management

At present no reservoir is being managed scientifically. Presence of major carps in the catches indicates stocking of these species but actual figures are wanting. The reservoirs are being exploited by various means and the necessary effort is available. What is needed is a sound management programme based on the yield potential and availability of fish food resources. A brief outline on the scope for management of individual reservoir is given below.

Srisailam Reservoir

Cast net operation in Srisailam Reservoir

A haul of *C.catla* from Srisailam Reservoir

Table 10. Energy flow and fish production potential in reservoirs of A.P.

	Wyra	Musi	N. Sagar	Srisailam	Singur	LMD	Kadam	MPD	Somasila
Latitude	17°11'	17°14'	16°34'	16°50'	17°45'	18°24'	19°18'	14°52'	14°29'
Total visible radiation (K cal/m²/day)	2196	2195	2210	2196	2188	2181	2168	2231	2232
Total radiant energy (K cal/ha/yr x 10^6)	8015	8012	8066	8015	7996	7961	7913	8142	8145
Carbon production (K cal/ha/yr x 10^6)	70.0	222.5	30.4	50.0	36.5	34.7	50.5	40.4	38.6
Photosynthetic efficiency (%)	0.87	2.78	0.37	0.62	0.45	0.44	0.64	0.50	0.47
Organic carbon deposits (K cal/ha/yr x 10^6)	257.6	864.6	409.9	210.6	380.8	416.6	434.6	387.5	129.9
Potential fish production (K cal/ha/yr x 10^4)	19.09	-	8.30	13.65	9.96	9.46	13.78	11.02	10.58
Kg/ha/yr	159	-	69	114	83	79	115	92	88

Wyra reservoir

It is the only reservoir where *M. malcolmsonii* contributed substantially to the catch. The prawn is probably getting recruited naturally from river Krishna and negotiating the dam contributing to the autostocking. Besides prawn major carps are being caught at small size. There is a need in this reservoir to enhance the minimum mesh size from its present one of 2.5 cm. Traps should be directed for exploiting prawns and gill nets with minimum mesh of 10 cm (5.0cm bar) to exploit fishes. Wyra has a good population of zooplankton and fairly rich bottom fauna consisting of *Tendepes* and other dipteran larvae. Besides catla and rohu, addition of common carp should be considered for stocking to exploit the bottom biota. As the reservoir is shallow exploitation of common carp will not pose a problem. Wyra being a seasonal river, breeding and successful recruitment of stocked carps may not be possible warranting their continuous stocking. Though the fish production potential has been estimated around 160 kg it is likely that the actual yield would be much higher. A stocking programme with emphasis on catla and common carp along with rohu and mrigal on continuing basis should be undertaken to realise the potential. The stocking rate could be around 300-400 fingerlings/ha of size between 75-100 mm. If larger fingerlings (> 100 mm) could be stocked, the stocking rate may suitably be reduced.

Musi reservoir

It is a polluted reservoir with fish kills occurring during summer. Major carps, catfishes, miscellaneous fishes and prawns account for the commercial catch. The flushing rate of Musi is very low at 0.7 which makes the environment unfavourable during summer. Any effort to increase the flushing rate will have a salutory effect on the quality of water and its productivity. The reservoir is being exploited by 1200 units with minimum mesh size used being 1.2 mm. Fishing intensity appears to be rather high for the size of the reservoir. *M. malcolmsoni* is getting recruited through the river Krishna as in Wyra. The reservoir has a fairly rich crop of zooplankton and equally rich bottom fauna consisting of larvae of chironomids and other dipterans. No farm facility is available at the reservoir. It is worthwhile to consider stocking Tilapia and murrels (*Channa striatus* and *C. punctatus*) which thrive well under testing conditions as obtained in Musi. Addition of common carp could also be considered to exploit the rich bottom fauna. The minimum mesh size may be raised suitably depending on the type of fishery developed.

Lentic view of Lower Manair Dam

Fish catch of Lower Manair Dam

Srisailam reservoir

It is the largest reservoir of the state in terms of area and also a productive one. Being spread out it poses considerable problems in exploitation and landing of the catch. Major carps are being exploited in considerable quantities. It is not known whether they are stocked or recruited from the downstream Nagarjunasagar. The reservoir has several incoming rivers which form suitable breeding grounds for major carps. The present studies are too inadequate to come up with any meaningful management measures. It is worthwhile to undertake detailed studies on this reservoir. Though N.sagar, the downstream reservoir has been studied in detail in seventies, Srisailam reservoir is a different category and needs a thorough study to understand its management problems.

Singur reservoir

It is relatively a new impoundment meant to supply water to Hyderabad city. Indications are that the reservoir is a medium productive one with moderate plankton density and fairly rich bottom fauna. Zooplankton is dominant in plankton and chironomid larvae and molluscs in bottom fauna. The reservoir is being exploited by about 226 units with gillnets employing thermocole rafts. The catches consisted of rohu, mrigal and indigenous fishes. It is necessary to develop fisheries in the reservoir not only to improve the fish productivity but also to keep the environment clean. Besides giving emphasis on stocking catla, rohu and mrigal, common carp and mahseer (*Tor khudree*) should also be included in the stocking programme. Inclusion of *T. khudree* will not only control molluscs but also helps in the conservation of this important species. Being a drinking water reservoir, pen and cage culture systems can not be introduced. The flushing rate of the reservoir is low and the water levels might go down drastically in summer due to exigencies of water requirement and the fishery manager will have no say in the matter of water management. Hence, the extent of reduction in area during summer should be taken into consideration while formulating measures for fisheries development. Thermocole rafts could be replaced by coracles to increase the efficiency of exploitation.

Lower Manair Dam

This is a large new impoundment of Godavari basin with medium productive potential. Besides inflows from catchment, it also receives water from Kakatiya canal as it is a balancing reservoir. The plankton and bottom fauna are at low to moderate density with dominance of zooplankton in the former and chironomid larvae in the latter. The fishing effort appears to be low. Catch consisted of a mixture of major carps and indigenous species. The flushing rate is about one indicating that the flood flows into the river above may not be adequate for successful breeding and recruitment of major carps. Stocking should include catla, mrigal and rohu in the order of importance with 50% of catla. Depending on the catches the fishing effort could be increased further by increasing the length of gillnets in each unit.

Kadam reservoir

It is a forty year old impoundment with favourable drainage and ecological features indicative of high production potential. Fish food resources are fairly rich with zooplankton prevailing in plankton and dipteran larvae in bottom biota. Fishery consisted of mostly indigenous fishes which include the mahseer, *T. khudree*. No stocking figures are available. The reservoir needs stocking support to realise the potential and the species should include catla, rohu and mrigal in the proportion of 4 : 3 : 3. Rate of stocking and size of seed could be as in Wyra. The reservoir has a farm attached where the necessary seed could be raised.

Mid-Penna reservoir

Main stream reservoir of river Penna, it gets much of inflows from the high level canal of Tungabhadra reservoir. It showed signs of productivity with strong oxycline and favourable drainage characteristics. It is rich in zooplankton and bottom macrofauna. The catch consisted of stocked carps and indigenous fishes. Fish species occurring in Tungabhadra reservoir such as *P. kolus, L. potail, M. seenghala* have also been observed. The stocked carps especially catla showed signs of good growth. The reservoir is being exploited by about 100 units employing gillnets, castnets and traps. The potential of the reservoir could be realised with stocking of catla, common carp, mrigal and rohu in the order of importance with greater emphasis on catla and common carp. Farm facilities are available at the dam to raise the necessary seed. No natural recruitment of major carps could be expected and the stocking should be on continuing basis.

Somasila reservoir

One of the recent impoundments, the reservoir showed signs of oligotrophy with weak oxycline and low abundance of fish food organisms. It is a balancing reservoir with more than half of inflows coming from Telugu Ganga Canal from Srisailam reservoir. At present about 64% of the catch consisted of carps. Catla and mrigal showed signs of good growth while that of rohu was poor. The reservoir needs stocking support with emphasis on catla and mrigal to realise the potential. About 1500 units of fishermen are exploiting the reservoir with gill nets. A farm also exists attached to the reservoir to raise the required seed.

Pollution

Rivers are frequently used as receptacles of effluent discharged from industries, city sewage, wastes from thermal power plants and municipalities and pesticides and fertilizers from agricultural lands through run-off. The pollution load carried by upstream rivers gets accumulated in reservoirs. Gradual accumulation of persistant chemicals in the sediments leads to the pollution of soil phase which in turn transferred to water phase and to the biota. The major determinants of pollution are the biological oxygen demand (BOD), chemical oxygen demand (COD), concentration of heavy metals and pesticide residues.

In the reservoirs under study, barring Musi, BOD values ranged from 1 to 2 mg/l during monsoon and post-monsoon months while in pre-monsoon months it was slightly higher in the range 1 to 3 mg/l. However, in Musi these values were higher in the range 5 to 15 mg/l. COD showed a range of 50 to 85 mg/l in Musi while in other reservoirs it ranged from 10 to 32 mg/l in post-monsoon and monsoon months and from 45 to 60 mg/l in pre-monsoon months. Kadam and MPD showed signs of pollution in pre- monsoon months.

Heavy metal pollution was not significant in any of the reservoirs (Table 11). In the sediments zinc was predominant among heavy metals and its concentration ranged between 97 (Somasila) to 143 mg/l (Musi). In water its concentration was within permissible limits in the range 0.014 (Kadam) to 0.057 mg/l (Somasila). Negative significant correlation (r = -0.724) was obtained in the concentration of zinc in sediments and water.

Copper was recorded in the range 46 to 98 mg/l (Singur) in sediments. However, in water it was detected only during monsoon season to the extent of 0.2 mg/l. Similarly, cadmium was detected only during pre-monsoon season both in sediment and water. In the sediment it was in the range 6.6 to 7.3 mg/l. The concentration of lead in the sediments varied from 22.6 (Wyra) to 41.3 mg/l (LMD) . In water it was detected during monsoon months to the extent of 0.33 to 0.37 mg/l which has reduced substantially in post-monsoon (0.052 to 0.091 mg/l) and could not be detected in pre-monsoon months.

Table 11. Heavy metal concentration (mean & range in mg/l) in sediment and water in reservoir

Reservoir	Zn		Cu		Cd		Pb	
	Sediment	*Water*	*Sediment*	*Water*	*Sediment*	*Water*	*Sediment*	*Water*
Wyra	**105** 73-149	**0.02** 0.01-0.03	**53.8** 47.1-63.3	ND-0.02	ND-7.0	ND-0.03	**22.6** ND-41.4	ND-0.37
Musi	**143** 118-167	**0.02** 0.004-0.03	**52.6** 43.8-68.1	ND-0.02	ND-6.6	ND-0.03	**39.1** 22.8-51.9	ND-0.37
N. Sagar	**139** 114-187	**0.03** 0.005-0.05	**92.7** 73.5-100	ND-0.02	ND-7.0	ND-0.03	**26.7** 16.8-32.0	ND-0.31
Srisailam	**89** 78-101	**0.04** 0.02-0.069	**70.8** 61.8-83.9	ND-0.02	ND-7.0	ND-0.03	**33.0** 25.7-37.4	ND-0.34
Singur	**139** 107-169	**0.02** 0.01-0.03	**98.6** 72.6-119.3	ND-0.02	ND-7.0	ND-0.03	**27.22** 21.5-31.9	ND-0.37
LMD	**129** 119-156	**0.03** 0.01-0.04	**48.4** 42.2-54.8	ND-0.02	ND-6.7	ND-0.03	**41.3** 39.0-45.7	ND-0.35
Kadam	**148** 111-192	**0.014** 0.009-0.02	**117.9** 8.3-142.4	ND-0.02	ND-7.3	ND-0.03	**28.6** 26.4-31.9	ND-0.33
MPD	**135** 77-183	**0.02** 0.02-0.02	**52.0** 41.9-68.1	ND-0.02	ND-6.6	ND-0.03	**37.2** 34.6-39.0	ND-0.34
Somasila	**97** 78-120	**0.057** 0.03-0.07	**46.3** 37.05-58.5	ND-0.02	ND-7.2	ND-0.03	**35.9** 29.3-42.8	ND-0.35

Mean values in bold figures, ND - Not detected

Table 11 .... Contd. /

95.16	1536.38	58.98				263.65	39798.36	5588.58	365.76	1615.53	145.62
95.77	1626.59	64.02				265.18	44536.26	6224.23			
						266.70	50602.63	6942.77			
						268.22	55721.42	7741.41			
						269.75	61518.38	8625.74			

Pesticide residues, particularly the stable organochlorine group, DDT, BHC and endosulphan were noticed in Musi during post-monsoon season. In the sediment the level of their concentration was 9, 370 and 12 ppb and in water 5, 150 and 4 ppb respectively. Total BHC residues were also detected in sediments of N. Sagar, Srisailam and Kadam in negligible quantities. In others, no pesticide was detected.

Conclusions

Most of the reservoirs have the necessary infrastructure for raising the seed and exploitation of the fishery (Table 12). Co-operative societies need to be activated and given the responsibility of management. The fishermen should be made partners in the management.

It is to the credit of private entrepreneurship in Andhra Pradesh, the state has come to occupy a leading position in the field of carp and shrimp culture. In view of this, it would be worthwhile leasing out selected reservoirs to the private sector on reasonably long-term basis. If succeeds it could be extended to more reservoirs.

The steep water level fluctuations in many reservoirs is a constraint to introduce pen culture to raise the seed. Reservoirs may be identified which favour pen culture operation for seed rearing. Any reservoir which gets filled up early in the monsoon and retain that level for 2 to 3 months would be suitable for pen rearing.

There is an immense scope to introduce cage culture systems in most of the reservoirs. This will enhance the yield from reservoir and also provide additional employment.

Table 12. Details of fish farms at selected reservoirs of A.P.

Reservoir	*Nursery ponds*		*Rearing ponds*		*Stocking ponds*		*Hatcheries*	*Total area (acres)*
	Size	***No.***	***Size***	***No.***	***Size***	***No.***	***No.***	
Somasila	30' x 15' x 3' (cement)	120	-	-	0.5 acre	1	-	n.a
	40' x 20' x 5' (earthen)							
M.P. Dam	50' x 15' x 4' (cement)	28	100' x 30' x 6'	3	-	-	-	n.a
Srisailam (Tangadancha farm)	20' x 10' x 4' (cement)	16	-	-	0.5 acre	5	-	9.2
	25' x 15' x 5' (earthen)	10						
Wyra	35' x 15' 4' (cement)	20	-	-	0.25	3	2	n.a
Kadam	75' x 25' x 3' (cement)	5	75' x 25' x 3'	2	-	-	-	-
	75' x 25' x 3' (earthen)	48	100' x 25' x 3'	2			-	-
L.M. Dam	10 x 5 m	25	15 x 5 m	10	0.5 acre	1	3	16.0
			15 x 10 m	4	0.01 acre	25		

No fish farm at Singur and Musi reservoirs

Appendix

Area and capacity at different levels in reservoirs of A.P.

Wyra Reservoir			*Musi Reservoir*			*Srisailam Reservoir*			*Mid-Penna Dam*		
Level (m)	Area (ha)	Capacity (10^6 m^3)	Level (m)	Area (ha)	Capacity (10^6 m^3)	Level (m)	Area (ha)	Capacity (10^6 m^3)	Level (m)	Area (ha)	Capacity (10^6 m^3)
90.28	521.17	12.18	185.93	293.38	6.55	240.79	6698.09	1302.03	342.90	74.32	3.26
90.59	554.43	13.90	187.45	467.75	12.24	242.32	7905.79	1411.93	344.42	97.55	4.56
90.89	588.61	15.76	188.98	682.63	20.86	243.84	9113.49	1540.08	345.95	128.20	6.24
91.20	646.86	17.80	190.50	973.59	33.30	245.36	10469.83	1687.50	347.47	176.51	8.54
91.50	707.71	20.04	192.02	1313.69	50.51	246.89	11835.46	1855.59	349.00	222.96	11.55
91.81	771.44	22.45	193.55	1657.34	72.82	248.41	13191.80	2044.11	350.52	269.41	15.26
92.11	837.77	25.08	195.07	2075.39	100.88	249.94	14557.43	2253.16	352.04	330.72	19.76
92.42	907.08	27.92	196.06	2506.72	135.41	251.46	16034.54	2483.82	353.57	405.97	25.30
92.72	981.40	30.97				252.98	17511.65	2736.72	355.09	495.16	32.6
93.02	1042.25	34.61				254.51	19378.94	3015.12	356.62	619.64	40.35
93.33	1123.72	37.75				256.03	21246.23	3320.52	358.14	820.31	51.22
93.63	1201.01	41.49				257.56	24590.63	3665.37	359.66	1011.68	65.03
93.94	1281.09	45.47				259.08	27535.03	4060.56	361.19	1195.62	81.67
94.24	1363.49	49.15				260.60	31511.68	4504.64	362.71	1342.41	100.84
94.55	1448.59	45.21				262.13	35961.59	5016.23	364.24	1491.51	122.18

Appendix (Continued)................

Singur Reservoir			*Lower Manair Dam*			*Kadam Reservoir*			*Somasila Reservoir*		
Level (m)	**Area (ha)**	**Capa-city (10^6 m^3)**	**Level (m)**	**Area (ha)**	**Capacity (10^6 m^3)**	**Level (m)**	**Area (ha)**	**Capacity (10^6 m^3)**	**Level (m)**	**Area (ha)**	**Capacity (10^6 m^3)**
511.00	1026.00	28.46	266.70	1560.72	58.69	205.74	1209.56	77.88	82.30	4041.15	211.88
512.00	1472.00	40.88	268.22	2094.90	86.19	207.26	1410.04	97.59	83.82	5360.33	282.69
513.00	2000.00	58.16	269.75	2605.85	122.20	208.79	1651.67	120.61	85.34	5657.61	365.74
514.00	2666.00	81.40	271.27	3346.26	167.65	210.31	1905.01	147.36	86.87	6503.00	458.08
515.00	3428.00	111.79	272.80	3985.41	222.81	211.84	2180.36	178.12	88.39	7710.70	565.24
516.00	4481.00	151.22	274.32	4682.16	290.60	213.36	2473.93	212.89	89.92	8407.45	686.64
517.00	5677.00	201.87	275.84	5583.29	365.17				91.44	9791.66	823.68
518.00	6764.00	264.00	277.37	6381.90	455.36				92.96	11287.35	982.52
519.00	7944.00	339.12	278.89	7215.88	557.61				94.49	11872.62	1157.04
520.00	8810.00	422.85	280.42	8102.43	672.96				96.01	14176.54	1340.05
521.00	9725.00	515.50							97.54	17493.07	1561.92
522.00	11650.00	619.53							99.06	19871.31	1829.18
523.00	15002.60	752.43							100.58	21348.42	2069.14